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(54) **ELASTIC TUBE ALIGNMENT AND FASTENING SYSTEM FOR PROVIDING PRECISE ALIGNMENT AND FASTENING OF COMPONENTS**

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(71) Applicant: **GM GLOBAL TECHNOLOGY OPERATIONS LLC**, Detroit, MI (US)

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(72) Inventors: **Steven E. Morris**, Fair Haven, MI (US); **Jennifer P. Lawall**, Waterford, MI (US)

“An Anti Backlash Two-Part Shaft Coupling With Interlocking Elastically Averaged Teeth” by Mahadevan Balasubramaniam, Edmund Golaski, Seung-Kil Son, Krishnan Sriram, and Alexander Slocum, Precision Engineering, V. 26, No. 3, Elsevier Publishing, Jul. 2002.

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(73) Assignee: **GM GLOBAL TECHNOLOGY OPERATIONS LLC**, Detroit, MI (US)

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Primary Examiner — Glenn Dayoan

Assistant Examiner — Melissa A Black

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(74) Attorney, Agent, or Firm — Cantor Colburn LLP

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(57) **ABSTRACT**

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An elastically averaged alignment system includes a first component having a first alignment member, an attachment element, and a support element, and a second component having a second alignment member, an alignment aperture, and an engagement surface that engages with the support element. The attachment element includes an attachment portion and an elastically deformable alignment element portion. The elastically deformable alignment element portion is configured and disposed to interferingly, deformably and matingly engage the alignment aperture. The attachment portion includes a hollow tube having a first wall thickness, and the elastically deformable alignment element portion includes a hollow tube having a second wall thickness less than the first wall thickness. Portions of the elastically deformable alignment element portion when inserted into the alignment aperture elastically deform to an elastically averaged final configuration that aligns the first alignment member with the second alignment member in at least two planar orthogonal directions.

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CPC **B62D 27/04** (2013.01); **B62D 27/065** (2013.01); **Y10T 29/53** (2015.01)

(58) **Field of Classification Search**
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See application file for complete search history.

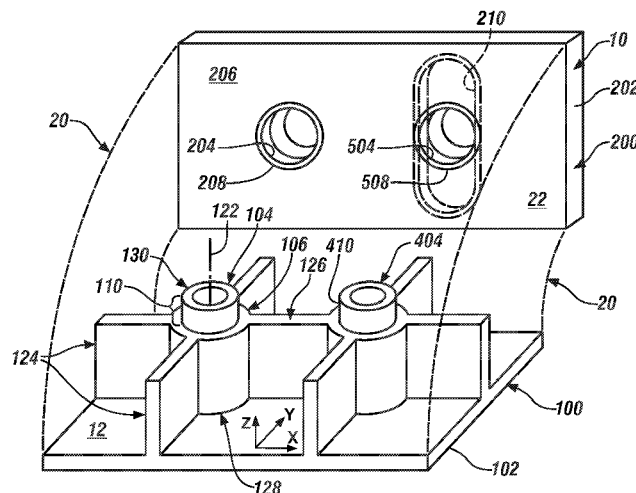
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20 Claims, 7 Drawing Sheets



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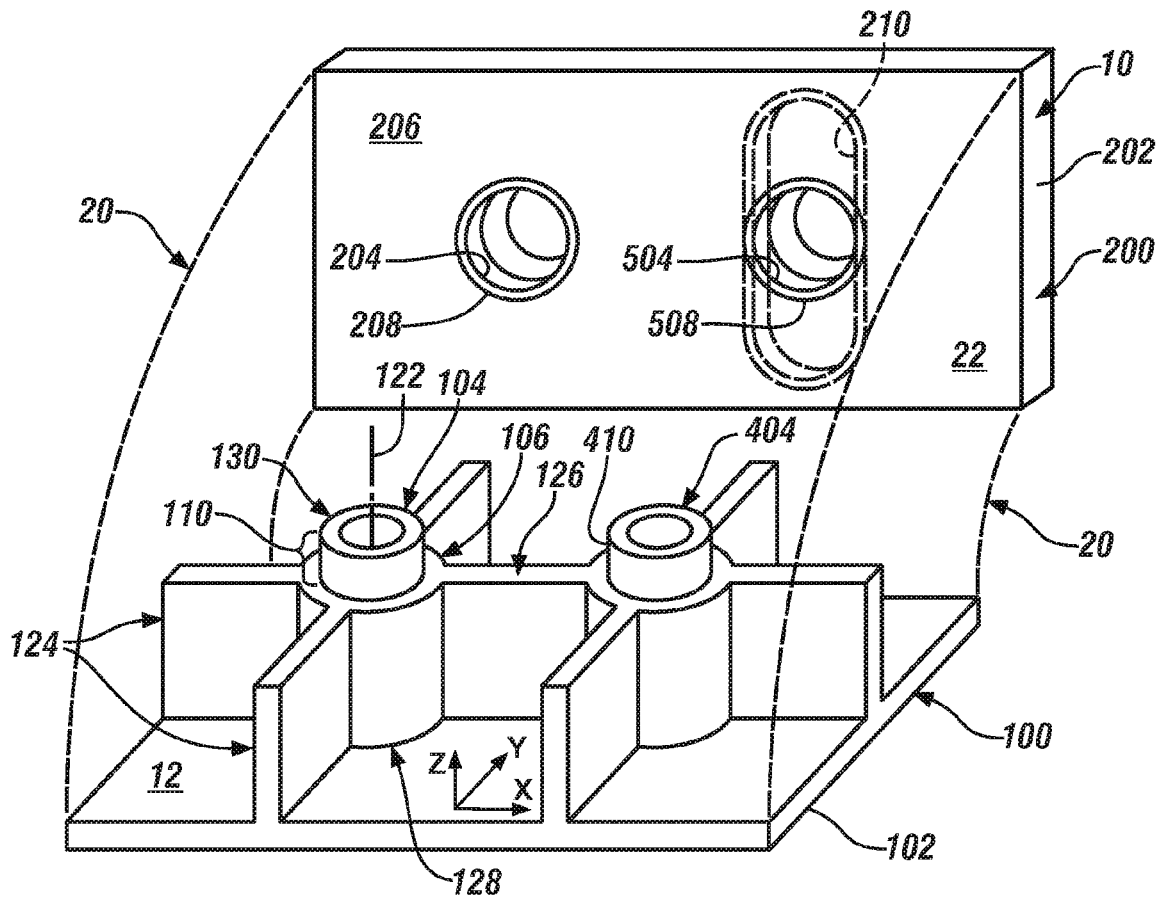


FIG. 1

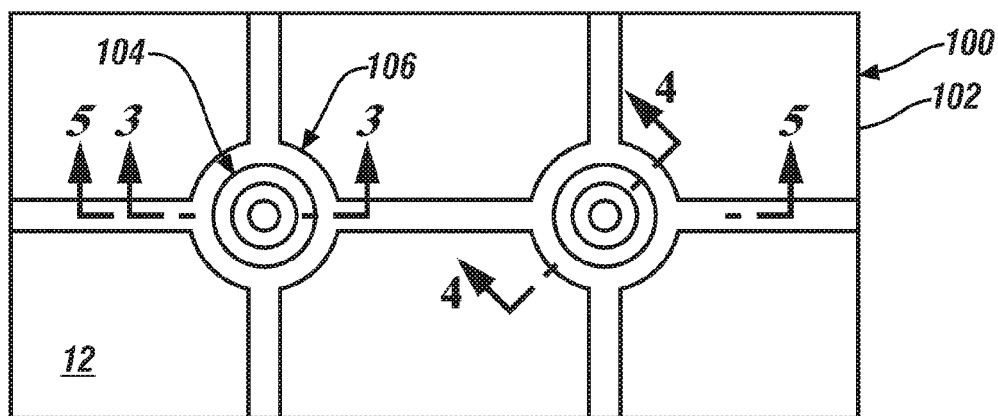


FIG. 2

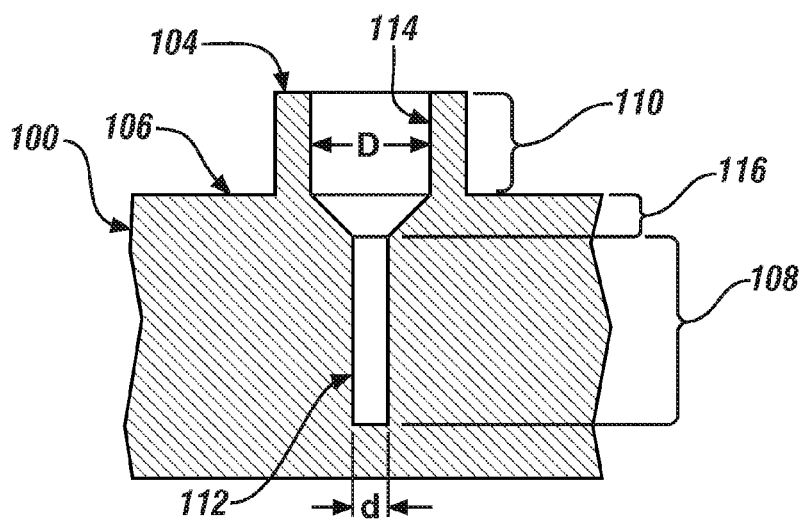


FIG. 3

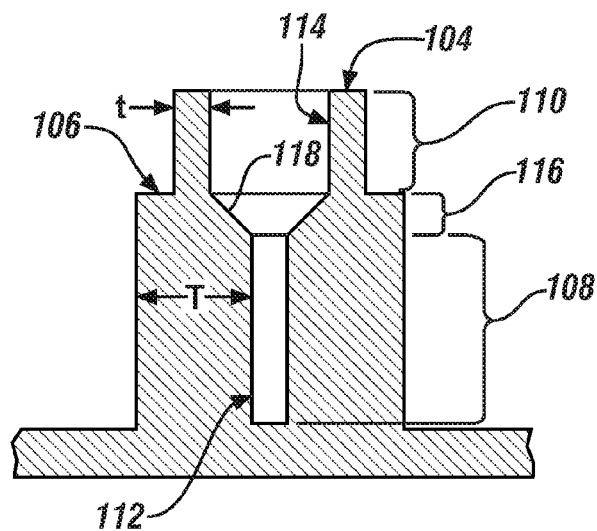


FIG. 4

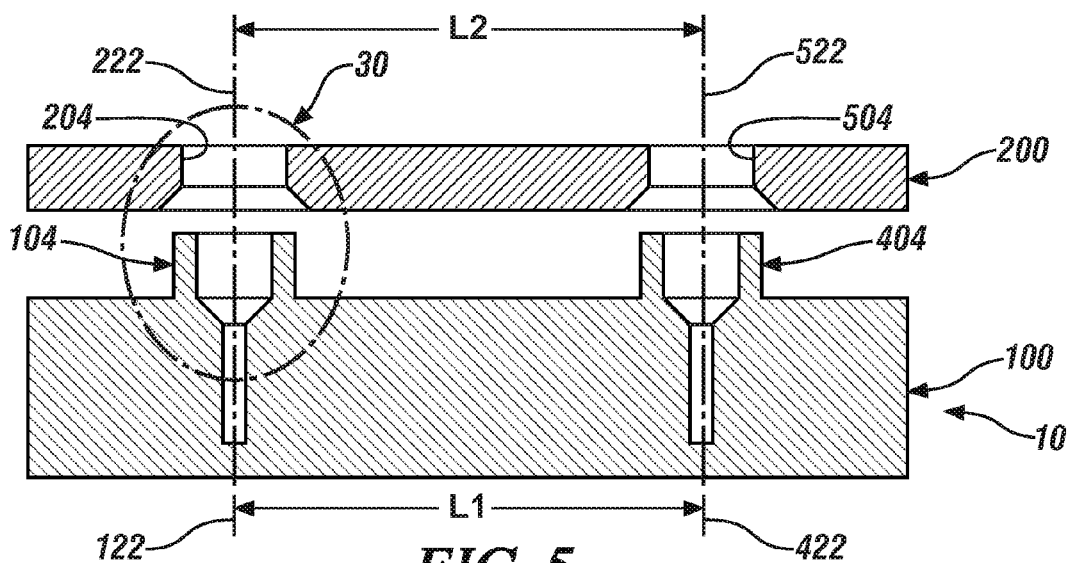


FIG. 5

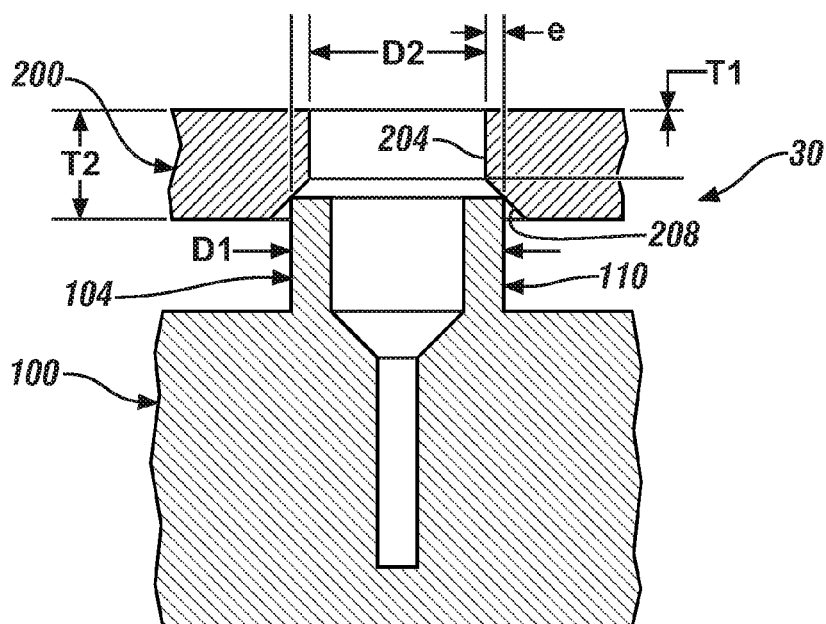


FIG. 6

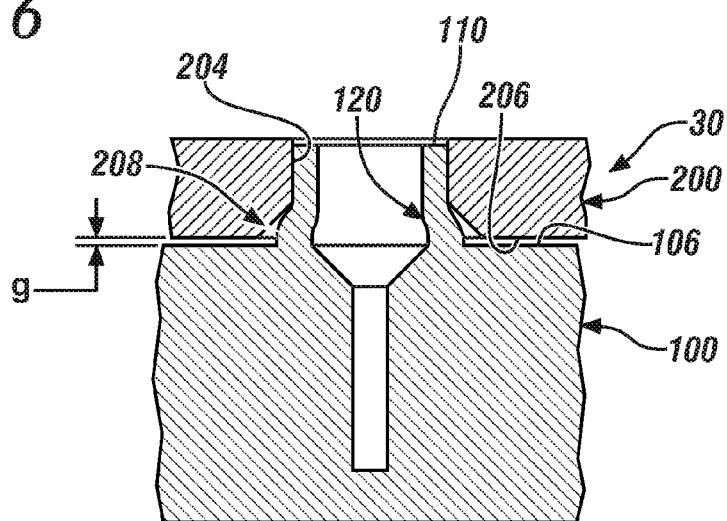


FIG. 7

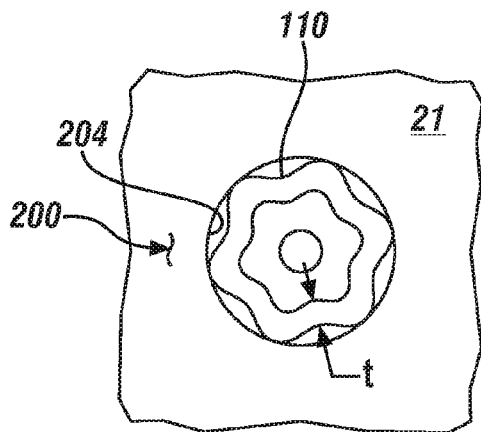


FIG. 8

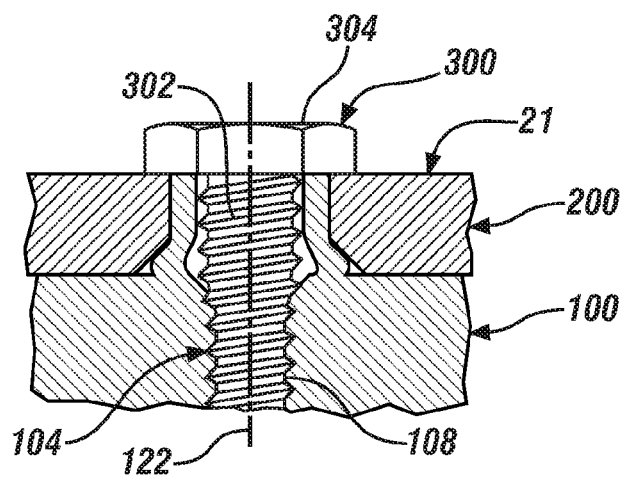


FIG. 9

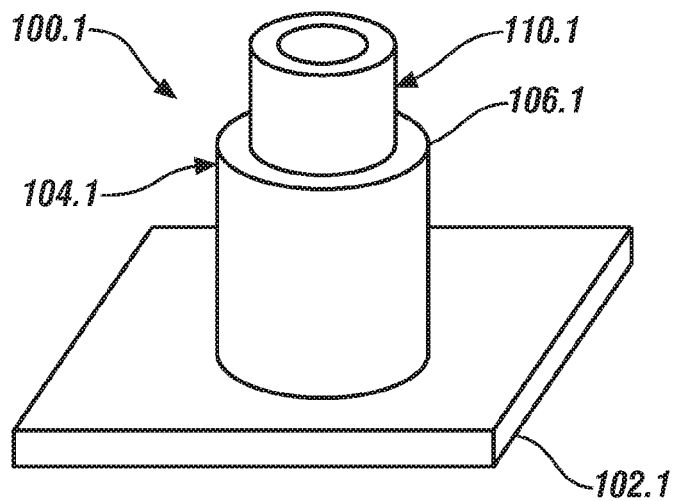


FIG. 10

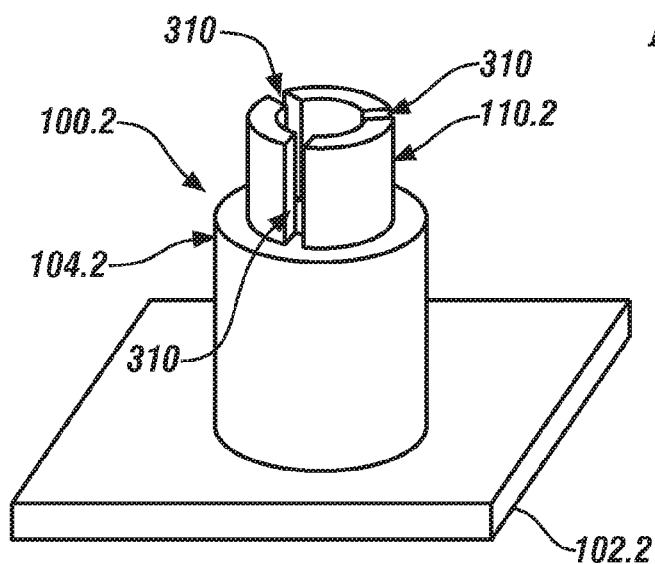


FIG. 11

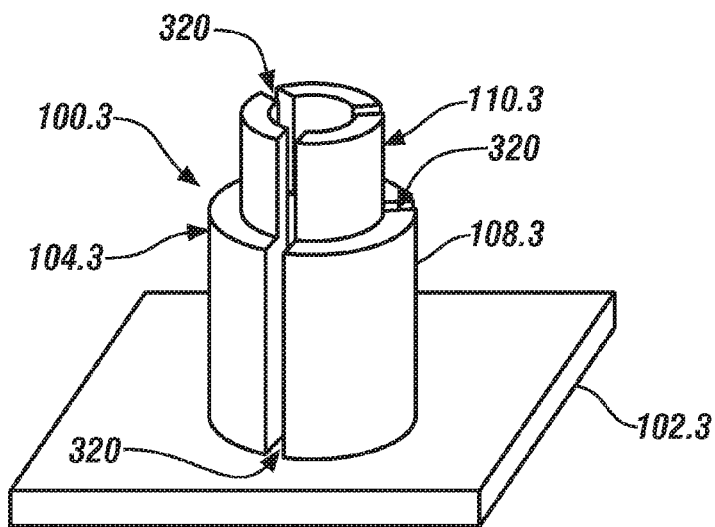


FIG. 12

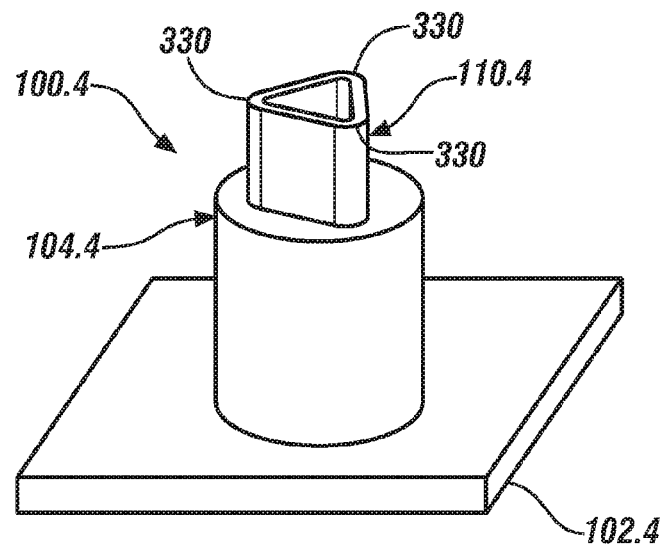


FIG. 13

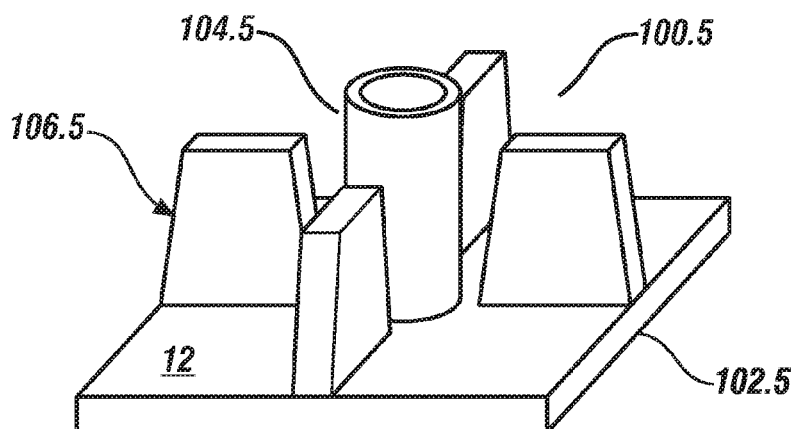


FIG. 14

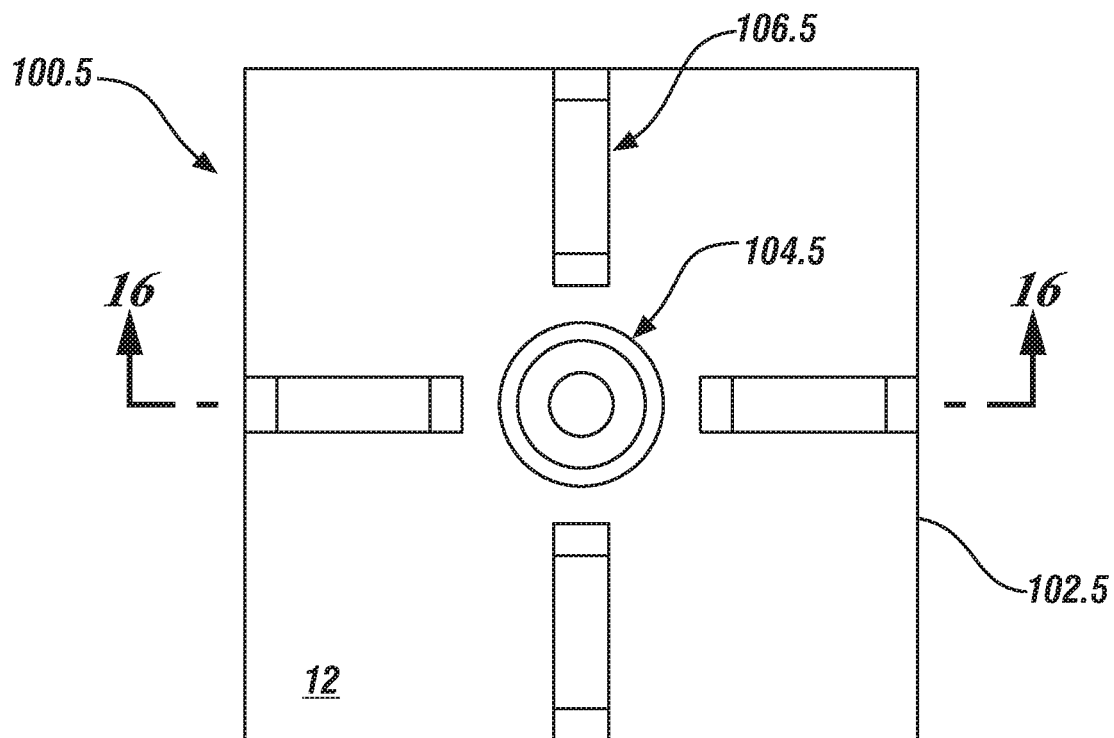


FIG. 15

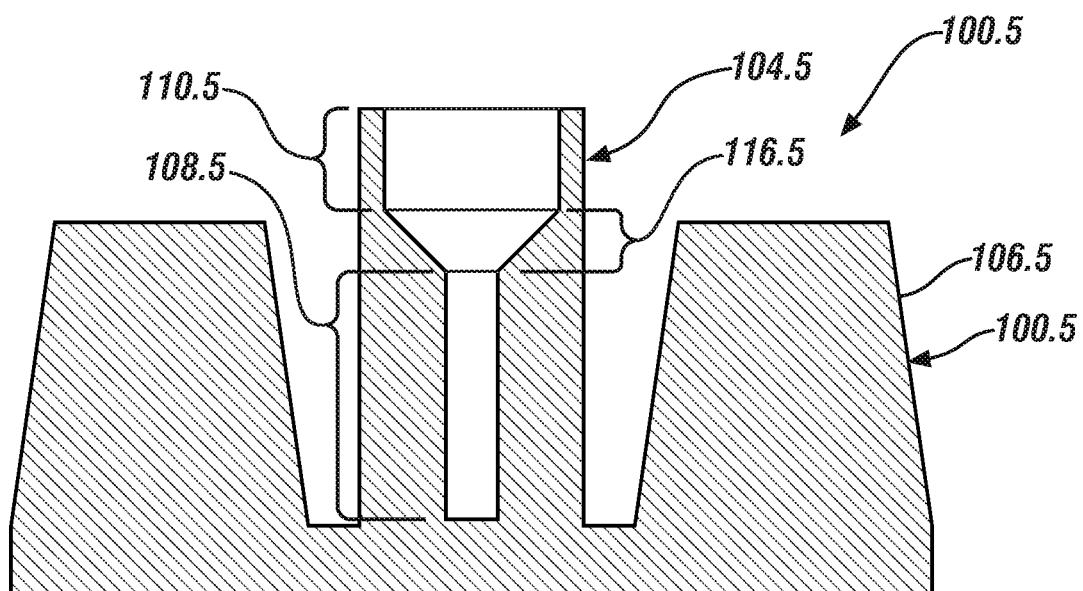


FIG. 16

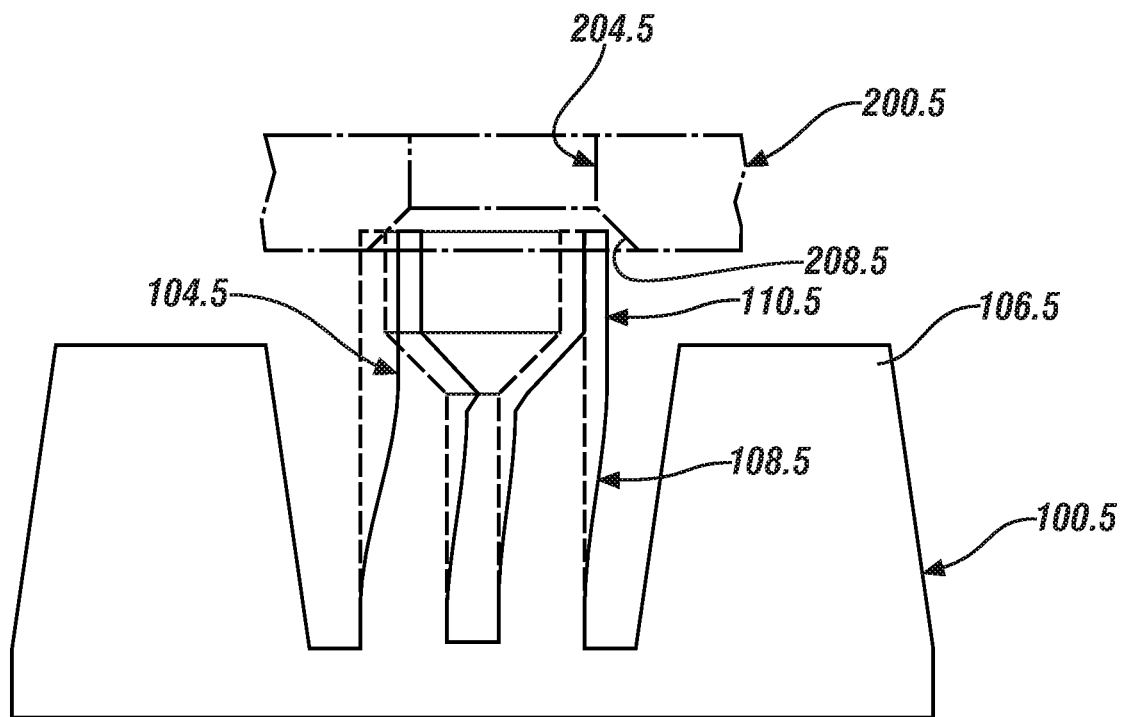


FIG. 17

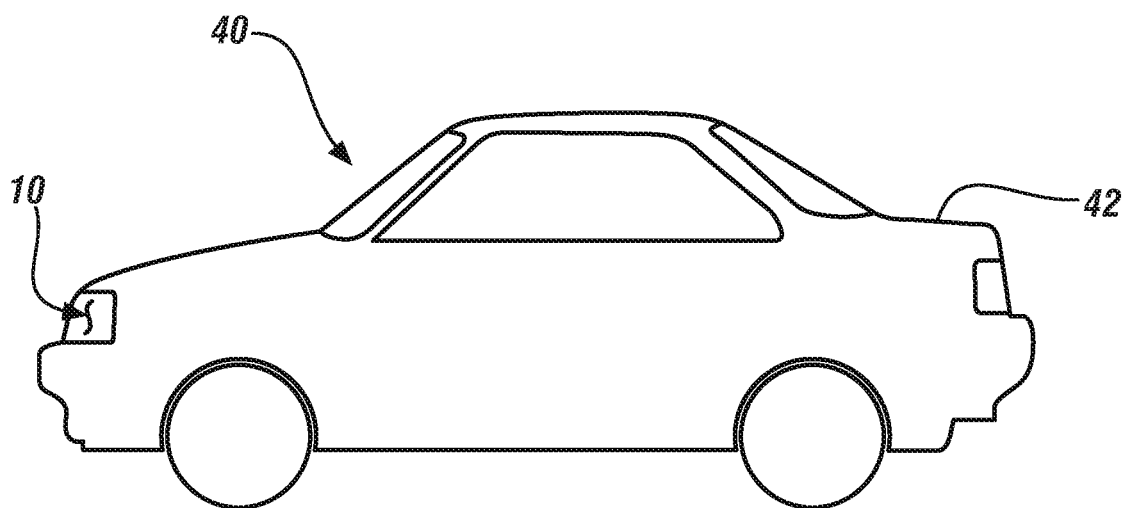


FIG. 18

1

ELASTIC TUBE ALIGNMENT AND FASTENING SYSTEM FOR PROVIDING PRECISE ALIGNMENT AND FASTENING OF COMPONENTS

FIELD OF THE INVENTION

The subject invention relates to the art of alignment systems, more particularly to an elastically averaged alignment system, and even more particularly to an elastically averaged alignment system providing alignment and fastening of mating components on which the alignment system is incorporated.

BACKGROUND

Currently, components, particularly vehicular components such as those found in automotive vehicles, which are to be mated together in a manufacturing process are mutually located with respect to each other by alignment features that are oversized and/or undersized to provide spacing to freely move the components relative to one another to align them without creating an interference therebetween that would hinder the manufacturing process. One example includes two-way and/or four-way male alignment features, typically upstanding bosses, which are received into corresponding female alignment features, typically apertures in the form of holes or slots. There is a clearance between the male alignment features and their respective female alignment features which is predetermined to match anticipated size and positional variation tolerances of the male and female alignment features as a result of manufacturing (or fabrication) variances. As a result, significant positional variation can occur between the mated first and second components having the aforementioned alignment features, which may contribute to the presence of undesirably large variation in their alignment, particularly with regard to the gaps and spacing between them. In the case where these misaligned components are also part of another assembly, such misalignments can also affect the function and/or aesthetic appearance of the entire assembly. Regardless of whether such misalignment is limited to two components or an entire assembly, it can negatively affect function and result in a perception of poor quality.

To align and secure components, the aforementioned male and female alignment features may be employed in combination with separate screw boss features that serve to secure the components to each other. In such an assembly, the mating components are located relative to each other by the alignment features, and are fixed relative to each other by the separate screw boss features. Use of two separate sets of features, one for alignment and the other for securement, may limit the effectiveness of each set on a given assembly, as one set of features cannot be employed where the other one is employed.

Accordingly, the art of alignment and securement systems can be enhanced by providing an alignment system with an integrally arranged fastening system that can ensure both alignment and fastening of two components via elastic averaging of a single elastically deformable alignment and fastening element disposed in mating engagement with a corresponding single alignment feature.

SUMMARY OF THE INVENTION

In one exemplary embodiment of the invention, an elastically averaged alignment system includes a first compo-

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nent and a second component. The first component includes a first alignment member, an attachment element, and a support element. The attachment element and the support element are fixedly disposed with respect to the first alignment member, and the support element is disposed proximate the attachment element. The attachment element includes an attachment portion and an elastically deformable alignment element portion. The second component includes a second alignment member, an alignment aperture, and an engagement surface configured to engage with the support element. The elastically deformable alignment element portion is configured and disposed to interferingly, deformably and matingly engage the alignment aperture. The attachment portion includes a hollow tube having a first wall thickness, and the elastically deformable alignment element portion includes a hollow tube having a second wall thickness less than the first wall thickness. Portions of the elastically deformable alignment element portion when inserted into the alignment aperture elastically deform to an elastically averaged final configuration that aligns the first alignment member with the second alignment member in at least two planar orthogonal directions.

In another exemplary embodiment of the invention, a vehicle includes a body and an elastically averaged alignment system integrally arranged with the body. The elastically averaged alignment system includes a first component and a second component. The first component includes a first alignment member, an attachment element, and a support element. The attachment element and the support element are fixedly disposed with respect to the first alignment member, and the support element is disposed proximate the attachment element. The attachment element includes an attachment portion and an elastically deformable alignment element portion. The second component includes a second alignment member, an alignment aperture, and an engagement surface configured to engage with the support element. The elastically deformable alignment element portion is configured and disposed to interferingly, deformably and matingly engage the alignment aperture. The attachment portion includes a hollow tube having a first wall thickness, and the elastically deformable alignment element portion includes a hollow tube having a second wall thickness less than the first wall thickness. Portions of the elastically deformable alignment element portion when inserted into the alignment aperture elastically deform to an elastically averaged final configuration that aligns the first alignment member with the second alignment member in at least two planar orthogonal directions. A fastener having a thread portion and a head portion is threadably engaged with the attachment portion via the thread portion, and the head portion is disposed to constrain the second component in at least an axial direction with respect to a central axis of the attachment element;

The above features and advantages and other features and advantages of the invention are readily apparent from the following detailed description of the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features, advantages and details appear, by way of example only, in the following detailed description of embodiments, the detailed description referring to the drawings in which:

FIG. 1 depicts an isometric perspective of a disassembled assembly of an elastically averaged alignment system hav-

ing a first component and a second component, in accordance with an embodiment of the invention;

FIG. 2 depicts a front plan view of the first component of the disassembled assembly of FIG. 1, in accordance with an embodiment of the invention;

FIG. 3 depicts a cross-section view of a portion of the first component of FIGS. 1 and 2, in accordance with an embodiment of the invention;

FIG. 4 depicts a cross-section view of another portion of the first component of FIGS. 1 and 2, in accordance with an embodiment of the invention;

FIG. 5 depicts a cross-section view of another portion of the first component of FIGS. 1 and 2, in accordance with an embodiment of the invention;

FIG. 6 depicts a cross-section view of a portion of the first and second components of FIG. 1 at a first stage of assembly just prior to the occurrence of elastic deformation, in accordance with an embodiment of the invention;

FIG. 7 depicts a cross-section view of the portion of the first and second components of FIG. 6 at a second stage of assembly after the occurrence of elastic deformation and just prior to full seating of the first and second components, in accordance with an embodiment of the invention;

FIG. 8 depicts a rear side plan view of the assembly of FIG. 7 illustrating an embodiment with elastic deformation, in accordance with an embodiment of the invention;

FIG. 9 depicts a cross-section view similar to that of FIG. 7 but after full seating of the first and second components and with a fastener engaged, in accordance with an embodiment of the invention;

FIG. 10 depicts an isometric perspective of an alternative first component, in accordance with an embodiment of the invention;

FIG. 11 depicts an isometric perspective of another alternative first component, in accordance with an embodiment of the invention;

FIG. 12 depicts an isometric perspective of another alternative first component, in accordance with an embodiment of the invention;

FIG. 13 depicts an isometric perspective of another alternative first component, in accordance with an embodiment of the invention;

FIG. 14 depicts an isometric perspective of an alternative first component similar to that of FIG. 1, but having an attachment element separated from surrounding support elements, in accordance with an embodiment of the invention;

FIG. 15 depicts a front plan view of the first component of FIG. 14, in accordance with an embodiment of the invention;

FIG. 16 depicts a cross-section view of the first component through a cut line depicted in FIG. 15, in accordance with an embodiment of the invention;

FIG. 17 depicts the cross-section view of FIG. 16 (cross-section lines omitted for clarity) in a partially assembled state with respect to a mating second component depicted in dotted line fashion, with dashed lines representing an undeformed state of assembly of the first component, and solid lines representing an elastically deformed state of assembly (exaggerated for illustration purposes) of the first component, in accordance with an embodiment of the invention; and

FIG. 18 depicts a vehicle with an elastically averaged alignment system, in accordance with an embodiment of the invention.

DESCRIPTION OF THE EMBODIMENTS

The following description is merely exemplary in nature and is not intended to limit the present disclosure, its

application or uses. For example, certain embodiments shown comprise vehicle body panels but the alignment and fastening system may be used with any suitable components to provide elastic averaging for precision location, alignment and fastening of all manner of mating components and component applications, including many industrial, consumer product (e.g., consumer electronics, various appliances and the like), transportation, energy and aerospace applications, and particularly including many other types of vehicular components and applications, such as various interior, exterior and under hood vehicular components and applications. It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features.

As used herein, the term “elastically deformable” refers to components, or portions of components, including component features, comprising materials having a generally elastic deformation characteristic, wherein the material is configured to undergo a resiliently reversible change in its shape, size, or both, in response to application of a force. The force causing the resiliently reversible or elastic deformation of the material may include a tensile, compressive, shear, bending or torsional force, or various combinations of these forces. The elastically deformable materials may exhibit linear elastic deformation, for example that described according to Hooke’s law, or non-linear elastic deformation.

Elastic averaging provides elastic deformation of the interface(s) between mated components, wherein the average deformation provides a precise alignment, the manufacturing positional variance being minimized to X_{min} , defined by $X_{min}=X/\sqrt{N}$, wherein X is the manufacturing positional variance of the locating features of the mated components and N is the number of features inserted. To obtain elastic averaging, an elastically deformable component is configured to have at least one feature and its contact surface(s) that is over-constrained and provides an interference fit with a mating feature of another component and its contact surface(s). The over-constrained condition and interference fit resiliently reversibly (elastically) deforms at least one of the at least one feature or the mating feature, or both features. The resiliently reversible nature of these features of the components allows repeatable insertion and withdrawal of the components that facilitates their assembly and disassembly. In some embodiments, the elastically deformable component configured to have the at least one feature and associated mating feature disclosed herein may require more than one of such features, depending on the requirements of a particular embodiment. Positional variance of the components may result in varying forces being applied over regions of the contact surfaces that are over-constrained and engaged during insertion of the component in an interference condition. It is to be appreciated that a single inserted component may be elastically averaged with respect to a length of the perimeter of the component. The principles of elastic averaging are described in detail in commonly owned, co-pending U.S. patent application Ser. No. 13/187,675, the disclosure of which is incorporated by reference herein in its entirety. The embodiments disclosed above provide the ability to convert an existing component that is not compatible with the above-described elastic averaging principles, or that would be further aided with the inclusion of an elastic averaging and fastening system as herein disclosed, to an assembly that does facilitate elastic averaging and the benefits associated therewith.

Any suitable elastically deformable material may be used for the mating components and alignment features disclosed herein and discussed further below, particularly those mate-

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rials that are elastically deformable when formed into the features described herein. This includes various metals, polymers, ceramics, inorganic materials or glasses, or composites of any of the aforementioned materials, or any other combinations thereof suitable for a purpose disclosed herein. Many composite materials are envisioned, including various filled polymers, including glass, ceramic, metal and inorganic material filled polymers, particularly glass, metal, ceramic, inorganic or carbon fiber filled polymers. Any suitable filler morphology may be employed, including all shapes and sizes of particulates or fibers. More particularly any suitable type of fiber may be used, including continuous and discontinuous fibers, woven and unwoven cloths, felts or tows, or a combination thereof. Any suitable metal may be used, including various grades and alloys of steel, cast iron, aluminum, magnesium or titanium, or composites thereof, or any other combinations thereof. Polymers may include both thermoplastic polymers or thermoset polymers, or composites thereof, or any other combinations thereof, including a wide variety of co-polymers and polymer blends. In one embodiment, a preferred plastic material is one having elastic properties so as to deform elastically without fracture, as for example, a material comprising an acrylonitrile butadiene styrene (ABS) polymer, and more particularly a polycarbonate ABS polymer blend (PC/ABS). The material may be in any form and formed or manufactured by any suitable process, including stamped or formed metal, composite or other sheets, forgings, extruded parts, pressed parts, castings, or molded parts and the like, to include the deformable features described herein. The elastically deformable alignment features and associated component may be formed in any suitable manner. For example, the elastically deformable alignment features and the associated component may be integrally formed, or they may be formed entirely separately and subsequently attached together. When integrally formed, they may be formed as a single part from a plastic injection molding machine, for example. When formed separately, they may be formed from different materials to provide a predetermined elastic response characteristic, for example. The material, or materials, may be selected to provide a predetermined elastic response characteristic of any or all of the elastically deformable alignment features, the associated component, or the mating component. The predetermined elastic response characteristic may include, for example, a predetermined elastic modulus.

As used herein, the term vehicle is not limited to just an automobile, truck, van or sport utility vehicle, but includes any self-propelled or towed conveyance suitable for transporting a burden.

In accordance with an exemplary embodiment of the invention, and with reference to FIG. 1, an elastically averaged alignment system 10 includes a first component 100 having a first alignment member 102, an attachment element 104, and a support element 106 disposed proximate the attachment element 104, and further includes a second component 200 having a second alignment member 202, an alignment aperture 204, and an engagement surface 206 configured to engage with the support element 106. In an embodiment, the second alignment member 202 includes a chamfer 208 on its respective engagement side that circumscribes at least a portion of the alignment aperture 204 and serves to facilitate insertion of the attachment element 104.

Each of the attachment element 104 and the support element 106 are fixedly disposed with respect to the first alignment member 102, and in an embodiment are integrally formed with the first alignment member 102 to form a single

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part. The attachment element 104 includes an attachment portion 108 and an integrally formed elastically deformable alignment element portion 110 (best seen with reference to FIGS. 3 and 4). The elastically deformable alignment element portion 110 is configured and disposed to interfittingly, deformably and matingly engage the alignment aperture 204 when the first and second components 100, 200 are mated together, which will be discussed in more detail below. The chamfer 208 serves to facilitate insertion of the elastically deformable alignment element portion 110 into the alignment aperture 204.

As depicted in FIG. 1, the attachment element 104 has a proximal end 128 disposed proximate the first alignment member 102, and a distal end 130 disposed distal to the first alignment member 120. In an embodiment, the distal end 130 includes a taper, which may be provided by a draft angle machined into a plastic injection molding machine designed to fabricate the first component 100, or may be otherwise provided by a structural taper feature at the distal end 130 of the attachment element 104, which would further serve to facilitate insertion of the elastically deformable alignment element portion 110 into the alignment aperture 204.

For discussion purposes, the mating side of the first alignment member 102 visible in FIG. 1 is labeled 12, and the mating side of the second alignment member 202 visible in FIG. 1 is labeled 22. The non-visible sides of the first and second alignment members 102, 202 that are hidden from view in FIG. 1 are herein referred to by reference labels 11 and 21, respectively. For discussion purposes, the 12 and 22 sides are herein referred to as front views, and the 11 and 21 sides are herein referred to as rear views. Dashed lines 20 represent direction lines that may be traversed as the first and second components 100, 200 are assembled with respect to each other.

Reference is now made to FIGS. 1-4 in combination, where FIG. 2 depicts a front plan view of side 12 of the first alignment member 102, FIG. 3 depicts a cross-section view through a portion of the first component 100 along the cut line 3-3 depicted in FIG. 2, and FIG. 4 depicts a cross-section view through another portion of the first component 100 along the cut line 4-4 depicted in FIG. 2. As depicted, the attachment portion 108 includes a hollow tube 112 having a first inside diameter "d" (best seen with reference to FIG. 3) and a first wall thickness "T" (best seen with reference to FIG. 4), and the elastically deformable alignment element portion 110 includes a hollow tube 114 having a second inside diameter "D" greater than the first inside diameter "d", where $D > d$, and a second wall thickness "t" less than the first wall thickness "T", where $t < T$. The attachment element 104 also includes a transition portion 116 disposed between the attachment portion 108 and the elastically deformable alignment element portion 110, where the inside diameter "D" transitions via a taper 118 to the inside diameter "d" to assist with the insertion of a fastener into the attachment portion 108, which will be discussed in more detail below. In an embodiment, the wall thickness "t" of the elastically deformable alignment element portion 110 extends down to at least the support surface of the support element 106.

Reference is now made to FIGS. 5-8.

FIG. 5 depicts a cross-section view through an elongated portion of the first component 100 along the cut line 5-5 depicted in FIG. 2, with an associated cross-section view of the second component 200 disposed in a pre-assembly orientation.

FIG. 6 depicts a cross-section view of the portions of the first and second components 100, 200 identified in detail—

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30 in FIG. 5 just prior to engagement of the elastically deformable alignment element portion 110 with the alignment aperture 204. As depicted, the elastically deformable alignment element portion 110 has an outside dimension, in this instance diameter, D1 that is larger than the inside diameter D2 of the alignment aperture 204, such that a purposeful nominal circumferential interference of dimension "e" exists between the elastically deformable alignment element portion 110 and the alignment aperture 204. As depicted, the chamfer 208 has a depth of (T2-T1). In an embodiment, T1 is approximately equal to half of T2.

FIG. 7 depicts the same portions of FIG. 6 but now in substantially complete engagement with each other as depicted by the partial gap "g" between the support surface of the support element 106 of the first component 100, and the engagement surface 206 (side 22) of the second component 200 (best seen with reference to FIG. 1). As depicted, the elastically deformable alignment element portion 110 has been interferingly, deformably and matingly engaged with the alignment aperture 204, resulting in elastic deformation as indicated by the deformation at 120. In an embodiment, the chamfer 208 not only serves to provide a lead-in for insertion of the elastically deformable alignment element portion 110 into the alignment aperture 204, but also provides a relief in the area of the deformation at 120, thereby permitting the first and second components 100, 200 to fully seat with respect to each other with the gap "g" being taken to zero. As would be expected with an elastically deformable alignment element portion 110 in the form of a circular hollow tube as illustrated, elastic deformation of the wall thickness "t" (see FIG. 4) necessarily must occur in order for the elastically deformable alignment element portion 110 to fit within the alignment aperture 204, which will now be discussed with reference to FIG. 8.

FIG. 8 depicts a rear side plan view of a portion of side 21 of the second component 200 when the first and second components 100, 200 are engaged as depicted in FIG. 7. As depicted, the wall thickness "t" of the elastically deformable alignment element portion 110 is elastically deformed in a rippled manner, exaggerated for illustration purposes, to fit within the alignment aperture 204. While FIG. 8 depicts a certain number of deformation ripples, or lobes, it will be appreciated that the scope of the invention is not limited to the number of ripples or lobes illustrated, but also encompasses any manner of deformation consistent with an embodiment of the invention disclosed herein.

In view of the elastically deformable alignment element portion 110 and alignment aperture 204 depicted in FIGS. 2-8 being a circular hollow tube and a circular aperture, respectively, it will be appreciated that the resulting constraint provided by the elastically averaged alignment system 10 will result in four-way alignment. However, as indicated by the slotted aperture 210 illustrated in dashed line fashion in FIG. 1, it will be appreciated that the scope of the invention also encompasses two-way alignment. While the slotted aperture 210 is depicted in a vertical orientation (as viewed from the perspective of FIG. 1), it will be appreciated that the scope of the invention is not so limited, and also encompasses an arrangement where the slotted aperture 210 is oriented horizontal, or at any angle.

In view of the foregoing, it will be appreciated that an embodiment includes an elastically averaged alignment system 10 where portions of the elastically deformable alignment element portion 110 when inserted into the alignment aperture 204 elastically deform to an elastically averaged final configuration that aligns the first alignment member 102 with the second alignment member 202 in two planar

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orthogonal directions, such as the +/-x-direction or the +/-y-direction of an orthogonal coordinate system, for example, which is herein referred to as two-way alignment, and in another embodiment aligns the first alignment member 102 with the second alignment member 202 in four planar orthogonal directions, such as the +/-x-direction and the +/-y-direction of an orthogonal coordinate system, for example, which is herein referred to as four-way alignment.

Reference is now made to FIG. 9, which depicts a view similar to that of FIG. 7 but with first and second components 100, 200 being fully seated with respect to each other such that the gap "g" is zero, and with a fastener 300 having a thread portion 302 threadingly engaged with the attachment portion 108 and a head portion 304 seated against side 21 of the second component 200 so as to constrain the second component 200 in at least an axial direction with respect to a central axis 122 of the attachment element 104.

With reference back to FIG. 1, the support element 106 is illustrated as being a platform, or boss, that is part of the attachment element 104 and forms the wall thickness T" (see FIG. 4) of the attachment portion 108 with which the threaded fastener 300 engages. However, as also illustrated in FIG. 1 another support element 126 is provided by a plurality of ribs 124 that extend radially outward with respect to the central axis 122 of the attachment element 104. The ribs provide the radially extending support surfaces 126 that are configured to engage with the engagement surface 206 of the second component 200.

In view of the foregoing, it will be appreciated that an embodiment of the elastically averaged alignment system 10 provides an attachment element 104 and support element 106 in the form of a screw boss that not only elastically aligns with the alignment aperture 204, but also provides a fixation point and standoff support for the second component 200.

Alternative features of the foregoing description will now be discussed with reference to FIGS. 10-17.

FIG. 10 depicts an alternative first component 100.1 having an alignment member 102.1, an attachment element 104.1, and an elastically deformable alignment element portion 110.1, similar to the like named elements described above having like base reference numerals, but absent integrally formed ribs 124 (depicted in FIG. 1). A support element 106.1 having a ring-shaped support surface is disposed around the perimeter of and integrally formed with the elastically deformable alignment element portion 110.1 to provide an attachment element 104.1 that provides an elastically deformable screw boss. A cross-section view of the embodiment of FIG. 10 is represented by FIG. 4. The elastically deformable and attachment features described with reference to FIGS. 1-9 are equally applicable to the embodiment of FIG. 10.

FIG. 11 depicts an alternative first component 100.2 having an alignment member 102.2, an attachment element 104.2, and an elastically deformable alignment element portion 110.2, similar to the like named elements having like base reference numerals described in connection with FIG. 10, but having a plurality of slots 310 formed in the elastically deformable alignment element portion 110.2 in an axial direction with respect to the central axis 122 of the attachment element 104.2 (see reference numeral 122 in FIG. 9). The elastically deformable alignment element portion 110.2 with slots 310 is herein also referred to as a segmented tube. In the embodiment of FIG. 11, the slots 310 serve to reduce the stiffness of the walls of the elastically deformable alignment element portion 110.2, which is contemplated to reduce the degree of rippling (with reference to

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FIG. 8) of the elastically deformable alignment element portion **110.2** as it is interferingly, deformably, and matingly engaged with the alignment aperture **204** of the second component **200**, by permitting the gaps of the slots **310** to at least partially close during assembly as each segment will tilt inward due to the interference fit condition. While FIG. 11 depicts only three slots **310** and associated three segments, it will be appreciated that the scope of the invention is not so limited, and also encompasses any number of slots and segments suitable for a purpose disclosed herein.

FIG. 12 depicts an alternative first component **100.3** having an alignment member **102.3**, an attachment element **104.3**, and an elastically deformable alignment element portion **110.3**, similar to the like named elements having like base reference numerals described in connection with FIG. 11, but having a plurality of slots **320** formed in both the elastically deformable alignment element portion **110.3** and the attachment portion **108.3** in an axial direction with respect to the central axis **122** of the attachment element **104.3** (see reference numeral **122** in FIG. 9). The elastically deformable alignment element portion **110.3** and attachment portion **108.3** with slots **320** are herein also referred to as a segmented tube. In the embodiment of FIG. 12, the slots **320** serve to reduce the stiffness of the walls of both the elastically deformable alignment element portion **110.3** and the attachment portion **108.3**, which is contemplated to not only reduce the degree of rippling (with reference to FIG. 8) of the elastically deformable alignment element portion **110.3** as it is interferingly, deformably, and matingly engaged with the alignment aperture **204** of the second component **200** as discussed above, but also to provide a degree of bending from each segment of the attachment portion **108.3** for ease of assembly. While FIG. 12 depicts only three slots **320** and associated three segments, it will be appreciated that the scope of the invention is not so limited, and also encompasses any number of slots and segments suitable for a purpose disclosed herein.

FIG. 13 depicts an alternative first component **100.4** having an alignment member **102.4**, an attachment element **104.4**, and an elastically deformable alignment element portion **110.4**, similar to the like named elements having like base reference numerals described in connection with FIG. 10, but having a plurality of lobes **330** formed in the elastically deformable alignment element portion **110.4**. The lobes **330** extend outwardly with respect to the central axis **122** of the attachment element **104.1** (see reference numeral **122** in FIG. 9) in a manner and function fully described in co-pending patent application having Ser. No. 13/945,231, filed Jul. 18, 2013, which is herein incorporated by reference in its entirety. In the embodiment of FIG. 13, the lobes **330** serve to reduce the amount of surface contact with the associated alignment aperture **204** and allow space for the lobular tube **110.4** to deform into the gaps between the lobular tube **110.4** and the associated alignment aperture **204** without the walls of the lobular tube **110.4** collapsing in on itself, thereby reducing the degree of rippling (with reference to FIG. 8) of the elastically deformable alignment element portion **110.4** as it is interferingly, deformably, and matingly engaged with the alignment aperture **204** of the second component **200** as discussed above. While FIG. 13 depicts only three lobes **330**, it will be appreciated that the scope of the invention is not so limited, and also encompasses any number of lobes suitable for a purpose disclosed herein.

With reference back to FIGS. 1 and 5 in combination, the first and second components **100**, **200** may include not only a first attachment element **104** and first alignment aperture

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204, but may also include a second attachment element **404** having features similar to those described above in connection with the first attachment element **104** such as a second elastically deformable alignment element portion **410**, and a second alignment aperture **504** having features similar to those described above in connection with the first alignment aperture **204** such as a second chamfer **508**, where the second elastically deformable alignment element portion **410** is configured and disposed to interferingly, deformably and matingly engage with the second alignment aperture **504** in a manner previously described. In FIG. 5, the distance between the central axis **122** of the first attachment element **104** and the central axis **422** of the second attachment element **404** is labeled "L1" (also herein referred to as a first defined distance), and the distance between the center **222** of the first alignment aperture **204** and the center **522** of the second alignment aperture **504** is labeled "L2" (also herein referred to as a second defined distance).

While FIGS. 1 and 5 depict only two attachment elements **104**, **404** and two alignment apertures **204**, **504**, it will be appreciated that the scope of the invention is not so limited, and also encompasses three, four or more attachment elements and alignment apertures. In an embodiment having three attachment elements and three alignment apertures, relative rotation between the first and second components **100**, **200** can be eliminated.

A first elastic averaging arrangement includes an elastic averaging system **10** where $L1=L2$, and where each of the first and second elastically deformable alignment element portions **110**, **410** are slightly oversized with respect to their respective first and second alignment apertures **204**, **504**, thereby causing elastically averaged deformation of the first and second elastically deformable alignment element portions **110**, **410** as they are interferingly, deformably and matingly engaged with their respective first and second alignment apertures **204**, **504** in a manner described herein.

A second elastic averaging arrangement includes an elastic averaging system **10** where $L1>L2$ or $L1<L2$, and again where each of the first and second elastically deformable alignment element portions **110**, **410** are slightly oversized with respect to their respective first and second alignment apertures **204**, **504**. In this second scenario, not only do the first and second elastically deformable alignment element portions **110**, **410** undergo elastically averaged deformation as they are interferingly, deformably and matingly engaged with their respective first and second alignment apertures **204**, **504** in a manner described herein, but they also experience a bending stress due to the mismatch between $L1$ and $L2$. By replacing each of the attachment elements **104**, **404** interconnected with ribs **124** as depicted in FIG. 1 (herein referred to as reinforced attachment elements), with a slotted attachment element **104.3** absent any interconnected ribs as depicted in FIG. 12 (herein referred to as non-reinforced attachment elements), a lower bending stress in the attachment element can be achieved due to the presence of the slots **320**. From the foregoing, it will be appreciated that embodiments of the invention utilizing non-ribbed screw bosses **104**, **106**, such as those depicted in FIGS. 10-17, that are employed in pairs where $L1\neq L2$, will experience a slight bending stress during assembly of the first and second components **100**, **200**.

While FIGS. 1-13 depict the support element **106** being integrally formed with the attachment element **104**, it will be appreciated that the scope of the invention is not so limited and also encompasses an arrangement where the attachment element **104** and support element **106** are separated from each other, which will now be discussed with reference to

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FIGS. 14-17, where FIG. 14 depicts an isometric perspective of an alternative first component 100.5 having an attachment element 104.5 surrounded by a plurality of support elements 106.5, FIG. 15 depicts a front plan view of side 12 of the first component 100.5 of FIG. 14, FIG. 16 depicts a cross-section view of the first component 100.5 through cut line 16-16 depicted in FIG. 15, and FIG. 17 depicts the cross-section view of FIG. 16 in a partially assembled state with respect to a mating second component 200.5 (depicted in dot-dash line fashion) with dashed lines representing an un-deformed state of assembly of the first component 100.5 and solid lines representing an elastically deformed state of assembly (exaggerated for illustration purposes) of the first component 100.5. The cross-hatching in FIG. 17 has been omitted for clarity.

As illustrated, the attachment element 104.5 is separated from each support element 106.5, while both the attachment element 104.5 and the support elements 106.5 are integrally formed with the first alignment member 102.5. While FIGS. 14 and 15 depict four equally spaced support elements 106.5 having a trapezoidal shape, it will be appreciated that the scope of the invention is not so limited and encompasses any number, placement and shapes of support elements 106.5.

As depicted in FIG. 16, the attachment element 104.5 includes an elastically deformable alignment element portion 110.5, an attachment portion 108.5, and a transition portion 116.5, all having features and functions as described above. As depicted in FIG. 17, and in view of the attachment element 104.5 being separated from each support element 106.5, the attachment element 104.5, and more particularly the attachment portion 108.5, is permitted to elastically deform in a bending mode as the elastically deformable alignment element portion 110.5 interferingly, deformably and matingly engages with a slightly misaligned alignment aperture 204.5 of the mating second component 200.5. As discussed herein, a chamfer 208.5 assists with the lead in of the elastically deformable alignment element portion 110.5 into the alignment aperture 204.5. In an embodiment, the outer diameter of the elastically deformable alignment element portion 110.5 is slightly larger than the inner diameter of the alignment aperture 204.5, as depicted in FIG. 6, which results in elastically averaged deformation of the elastically deformable alignment element portion 110.5 once engaged with the alignment aperture 204.5, as depicted in FIG. 8. Accordingly, an embodiment includes an attachment element 104.5 configured to provide an elastically averaged alignment system 10 where the attachment element 104.5 is elastically deformed in both a compression mode and a bending mode, where L1 and L2 may not be equal.

While certain features have been described and illustrated herein in combination with other certain features, it will be appreciated that some features may be interchanged and or substituted and or combined with other features while remaining consistent with the disclosure herein and without detracting from the scope of the invention. For example, the attachment element 104.5 depicted in FIG. 16, or portions thereof, may include slots 310, 320 as depicted in FIGS. 11 and 12. All such combinations are contemplated and considered within the scope of the invention disclosed herein.

In view of all of the foregoing, and with reference now to FIG. 18, it will be appreciated that an embodiment of the invention also includes a vehicle 40 having a body 42 with an elastically averaged alignment system 10 as herein disclosed integrally arranged with the body 42. In the embodiment of FIG. 18, the elastically averaged alignment system 10 is depicted forming at least a portion of a front grill of the vehicle 40. However, it is contemplated that an elastically

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averaged alignment system 10 as herein disclosed may be utilized with other structural features of the vehicle 40, such as interior trim for example.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed, but that the invention will include all embodiments falling within the scope of the application.

What is claimed is:

1. An elastically averaged alignment system, comprising:
 - a first component comprising a first alignment member, an attachment element, and a support element, each of the attachment element and the support element fixedly disposed with respect to the first alignment member, the support element disposed proximate the attachment element, the attachment element comprising an attachment portion and an elastically deformable alignment element portion;
 - a second component comprising a second alignment member, an alignment aperture, and an engagement surface configured to engage with the support element; wherein the elastically deformable alignment element portion is configured and disposed to interferingly, deformably and matingly engage the alignment aperture; wherein the attachment portion comprises a hollow tube having a first wall thickness, and the elastically deformable alignment element portion comprises a hollow tube having a second wall thickness less than the first wall thickness; and wherein portions of the elastically deformable alignment element portion when inserted into the alignment aperture elastically deform to an elastically averaged final configuration that aligns the first alignment member with the second alignment member in at least two planar orthogonal directions.
2. The elastically averaged alignment system of claim 1, further comprising:
 - a fastener comprising a thread portion and a head portion, the thread portion being threadingly engaged with the attachment portion, and the head portion being disposed to constrain the second component in at least an axial direction with respect to a central axis of the attachment element.
3. The elastically averaged alignment system of claim 1, wherein:
 - portions of the elastically deformable alignment element when inserted into the alignment aperture elastically deform to an elastically averaged final configuration that aligns the first alignment member with the second alignment member in four planar orthogonal directions.
4. The elastically averaged alignment system of claim 1, wherein:
 - the elastically deformable alignment element portion comprises a hollow tube having a circular axial cross-section with respect to a central axis of the attachment element.
5. The elastically averaged alignment system of claim 1, wherein:
 - the elastically deformable alignment element portion comprises a hollow tube having an axial cross-section

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- comprising at least three outwardly oriented lobes with respect to a central axis of the attachment element.
6. The elastically averaged alignment system of claim 1, wherein:
- the attachment portion comprises a hollow tube having a circular axial cross-section with respect to a central axis of the attachment element.
7. The elastically averaged alignment system of claim 1, wherein:
- the hollow tube of the elastically deformable alignment element portion comprises at least one slot oriented in an axial direction with respect to a central axis of the attachment element.
8. The elastically averaged alignment system of claim 7, wherein:
- the hollow tube of the attachment portion comprises at least one slot oriented in an axial direction with respect to a central axis of the attachment element.
9. The elastically averaged alignment system of claim 1, wherein:
- the hollow tube of the elastically deformable alignment element portion comprises more than one slot oriented in an axial direction with respect to a central axis of the attachment element.
10. The elastically averaged alignment system of claim 1, wherein:
- the attachment element is elastically deformable.
11. The elastically averaged alignment system of claim 1, wherein:
- the support element is integral with the attachment element.
12. The elastically averaged alignment system of claim 1, wherein:
- the support element comprises a ring-shaped support surface disposed around a perimeter of the attachment element and configured to engage with the engagement surface of the second component.
13. The elastically averaged alignment system of claim 1, wherein:
- the support element comprises at least one rib that extends radially outward with respect to a central axis of the attachment element, the at least one rib having a radially extending support surface configured to engage with the engagement surface of the second component.
14. The elastically averaged alignment system of claim 1, wherein:
- the attachment element and the support element are integrally formed with the first alignment member to form a single part.
15. The elastically averaged alignment system of claim 1, wherein:
- the first component and the second component each have respective engagement sides relative to each other; and the second alignment member comprises a chamfer on its respective engagement side that circumscribes at least a portion of the alignment aperture.
16. The elastically averaged alignment system of claim 1, wherein:
- the attachment element comprises a proximal end proximate the first alignment member, and a distal end distal to the first alignment member, the distal end comprising a taper.
17. The elastically averaged alignment system of claim 1, wherein the attachment element is a first of a plurality of the attachment element, the support element is a first of a

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plurality of the support element, the alignment aperture is a first of a plurality of the alignment aperture, and further comprising:

- a second of the plurality of the attachment element fixedly disposed with respect to the first alignment member, and spaced apart from the first of the plurality of the attachment element a first defined distance;
- a second of the plurality of the support element fixedly disposed with respect to the first alignment member, and disposed proximate the second of the plurality of the attachment element;
- a second of the plurality of the alignment aperture spaced apart from the first of the plurality of the alignment aperture a second defined distance;
- wherein the elastically deformable alignment element portion of the second of the plurality of the attachment element is configured and disposed to interferingly, deformably and matingly engage the second of the plurality of the alignment aperture;
- wherein portions of respective ones of the elastically deformable alignment element portion of each of the first and second of the plurality of the attachment element when inserted into respective ones of the first and second of the plurality of the alignment aperture elastically deform to an elastically averaged final configuration that further aligns the first alignment member with the second alignment member in at least two planar orthogonal directions; and
- wherein a first portion of the second component is supported by the first of the plurality of the support element, and a second portion of the second component is supported by the second of the plurality of the support element.
18. The elastically averaged alignment system of claim 17, wherein the first defined distance is not equal to the second defined distance, and further wherein:
- each elastically deformable alignment element portion of the first and second attachment elements are configured to elastically deform in bending, absent deformation in bending of each respective attachment portion, when the first and second components are mated to each other.
19. The elastically averaged alignment system of claim 17, wherein the first defined distance is not equal to the second defined distance, and further wherein:
- each elastically deformable alignment element portion and each respective attachment portion of the first and second attachment elements are configured to elastically deform in bending when the first and second components are mated to each other.
20. A vehicle, comprising:
- a body; and
- an elastically averaged alignment system integrally arranged with the body, the elastically averaged alignment system comprising:
- a first component comprising a first alignment member, an attachment element, and a support element, each of the attachment element and the support element fixedly disposed with respect to the first alignment member, the support element disposed proximate the attachment element, the attachment element comprising an attachment portion and an elastically deformable alignment element portion;
- a second component comprising a second alignment member, an alignment aperture, and an engagement surface configured to engage with the support element;

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a fastener comprising a thread portion and a head portion,
the thread portion being threadingly engaged with the
attachment portion, and the head portion being dis-
posed to constrain the second component in at least an
axial direction with respect to a central axis of the 5
attachment element;
wherein the elastically deformable alignment element
portion is configured and disposed to interferingly,
deformably and matingly engage the alignment aper-
ture; 10
wherein the attachment portion comprises a hollow tube
having a first wall thickness, and the elastically deform-
able alignment element portion comprises a hollow
tube having a second wall thickness less than the first
wall thickness; and 15
wherein portions of the elastically deformable alignment
element portion when inserted into the alignment aper-
ture elastically deform to an elastically averaged final
configuration that aligns the first alignment member
with the second alignment member in at least two 20
planar orthogonal directions.

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